USDA FOREST SERVICE
RESEARCH NOTE RM- 232

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Age of Engelmann Spruce Seedlings Affects Ability to Withstand Low Temperature: *A Greenhouse Study*

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Spruce seedlings were exposed to 5°, 15°, and 25°F. cold treatments at 6 development stages—2 weeks through 12 weeks at 2-week intervals. All seedlings survived the 25°F., but no seedlings survived 5°F. At 15°F. few seedlings 2 to 8 weeks old survived, but most seedlings 10 to 12 weeks old survived. No correlation could be found between cold resistance and moisture content.

Keywords: *Picea engelmannii*, cold-hardiness, seedling moisture content.

Natural regeneration of Engelmann spruce (Picea engelmannii Parry) following clearcutting has been highly variable in the Rocky Mountains (Alexander 1966, 1968; Roe and Schmidt 1964). Research experience and general observations have indicated that lack of regeneration is often due to environmental factors associated with germination and first-year seedling survival (Roe et al. 1969). Environment is a complex integration of physical and biological factors which may be grouped in three broad categories: climatic, edaphic, and biotic. Climatic factors are most important (Roe et al. 1969, Ronco 1970).

Spruce grows in a cold, humid climate characterized by extremes (Alexander 1958). The average frost-free period for spruce at the Fraser Experimental Forest in the Central Rockies is less than 60 days, and below-freezing temperatures can occur during any month of the growing season. Weather records show that temperatures from mid-June to late September frequently reach a minimum of 26°-28°F., occasionally to 16°-18°F., and rarely drop to 6°-8°F. Furthermore, these temperatures may occur anytime during the period, although minimums below 20°F. are more likely to occur in late summer. Because of these extremes, low temperatures during the first few weeks of a seedling's life may limit regeneration success (Ronco 1967).

Spruce germination requires viable seed, favorable seedbed conditions, adequate soil moisture, air temperatures above freezing at night, and at least 60°F. during the day. The normal germination period is late June and early July, when these requirements are most likely to be met. However, if the seedbed is too cold or dry, germination may be delayed until midsummer rains in August. Furthermore, seedlings that germinate late in the growing season usually do not have time to harden off before late summer frosts. Generally, these seedlings are killed or severely damaged by low temperatures (Ronco 1967).

The purpose of this study was to determine: (1) if spruce seedlings become more resistant to low temperature as they develop during their first growing season, and (2) the relationship between cold-hardiness and moisture content.

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Methods and Materials

Two controlled-environment chambers were used. The greenhouse was the rearing-recovery chamber, and a walk-in refrigeration unit the low-temperature chamber.

Engelmann spruce seeds collected in 1966 on the Fool Creek drainage of the Fraser Experimental Forest were used. Forty seeds were sown in each of 120 standard, 6-inch plastic greenhouse pots filled with sandy loam soil collected from the spruce-fir zone in central Colorado. The pots were soaked twice daily for 3 days before seeding to insure that soil was near saturation. After initial watering, water was applied at the rate of 2.0 inches per month — 0.25 inch per application, eight times a month. Ten seedlings of the same germination date (± 1 day) were allowed to become established in each pot.

Seedlings were raised in a controlled greenhouse, with environmental conditions maintained as close as possible to field conditions in the spruce-fir zone during the growing season. The temperature regime was 70°F. days and 40°F. nights, with a photoperiod of 16 hours (natural light supplemented by artificial light of approximately 5,000 ft.-c.). The transition period for temperatures coincided with the photoperiod change. Relative humidity was held at approximately 20 percent during the day and 70 to 80 percent at night. Temperature and humidity were monitored by a hygrothermograph.

The design of the experiment was a two-factor factorial. Seedling development stage at six levels was arranged in a randomized block, with temperature treatments at four levels in a split plot. Each treatment combination was replicated five times. Seedling development stages were 2-week intervals from 2 weeks to 12 weeks after germination. Temperature treatments were 5°, 15°, and 25°F., and the greenhouse control.

When seedlings reached specified treatment ages, they were removed from the greenhouse and placed in the refrigeration unit for the prescribed low-temperature treatments. A hygrothermograph monitored ambient air temperature in the walk-in cooler. A telemeter with an air-temperature probe was used to check air temperatures within 1 mm. of the seedlings.

The pots were placed in a styrofoam container that provided a 2-inch layer of insulation on the sides and bottom of the pots. This styrofoam had an ambient temperature of 70°F. at the beginning of each low-temperature treatment. Therefore, only the soil surface and aerial portions of seedlings were immediately subjected to the low temperatures. The temperatures of the soil at 1-, 2-, and 3-inch depths were measured at 1-hour intervals during the 8 hours that seedlings were subjected to cold treatments. The telemeter with a soil probe was used for these soil temperature measurements. Soil temperatures were also measured while the seedlings were in the greenhouse.

Following each of the low-temperature treatments, seedlings were returned to the greenhouse for a 30-day recovery period. At the end of this recovery period, seedling survival, dry weight, and moisture content were measured.

Results and Discussion

Resistance to low temperature was related to development stage only at 15°F. At that temperature, 92 to 96 percent of the seedlings 10 and 12 weeks old survived, but only 2 percent or less survived at other development stages. On the other hand, all seedlings survived the 25°F. and control treatments, whereas no seedlings survived the 5°F. treatment.

There were no significant differences in moisture content or seedling dry weight between control seedlings, seedlings treated at 25°F., nor the last two development stages of the 15°F. treatment. Average seedling water content decreased (fig. 1) and dry weight increased (fig. 2) as seedlings grew older. No significant relationship was found between the change in cold-hardiness and seedling moisture content or seedling dry weight.

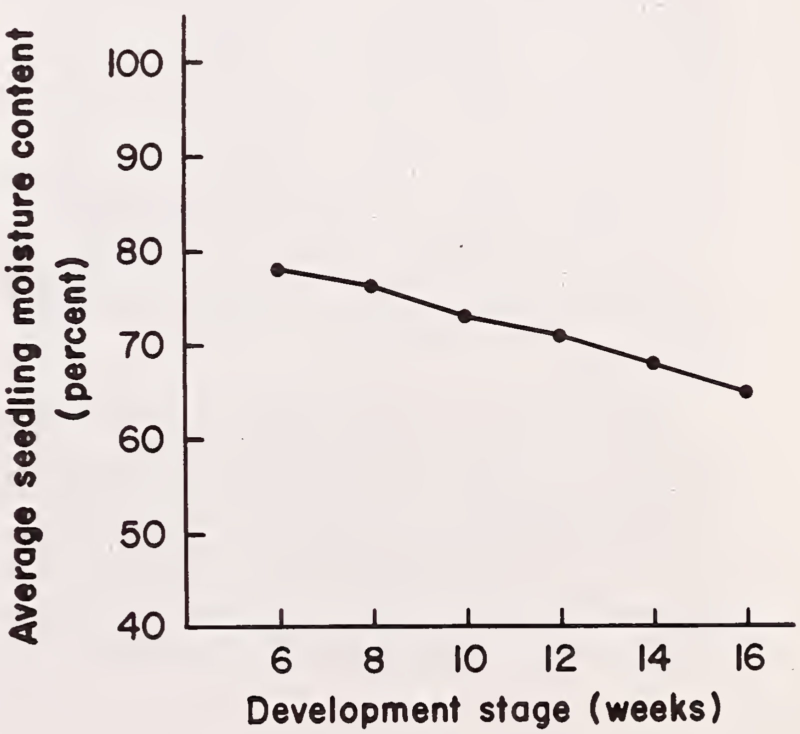

Figure 1.—Average seedling moisture content expressed as percentage for each development stage (moisture content measured after 30-day recovery period).

Soil temperatures measured in the controlled greenhouse environment were the same at depths of 1, 2, and 3 inches. The average minimum was 55°F., average maximum 72°F., and the 24-hour mean 61°F. Average soil temperatures decreased during the 8-hour cold treatments, but were not greatly different between the three treatments (fig. 3). There were no differences in soil temperatures at 1 to 3 inches in the 15°F. and 25°F. treatments. In the 5°F. treatment, however, the soil temperature at 1 inch dropped to 32°F., and approximately the upper 1/4 inch of soil froze. Soil temperatures at 2 and 3 inches averaged 34°F.

Since the soil temperatures for each cold treatment were similar, the sudden lowering of air temperatures surrounding the aerial portion of the seedlings probably caused most of the damage. Cell walls most likely were ruptured by the formation of intracellular ice crystals.

When seedlings reached the 8-week stage, they were just beginning to form terminal buds. By the 10th and 12th weeks, however, the terminal buds had set and primary needles appeared mature.

Results from greenhouse studies cannot be directly extrapolated to field conditions. Seedlings in the field may develop cold-hardiness at different rates. Nevertheless, this study has verified what investigators have observed in the field: older spruce seedlings are likely to withstand a sudden drop in temperature to as low as 15°F. in late summer or early fall, whereas seedlings that germinated late in the growing season have little probability of surviving.

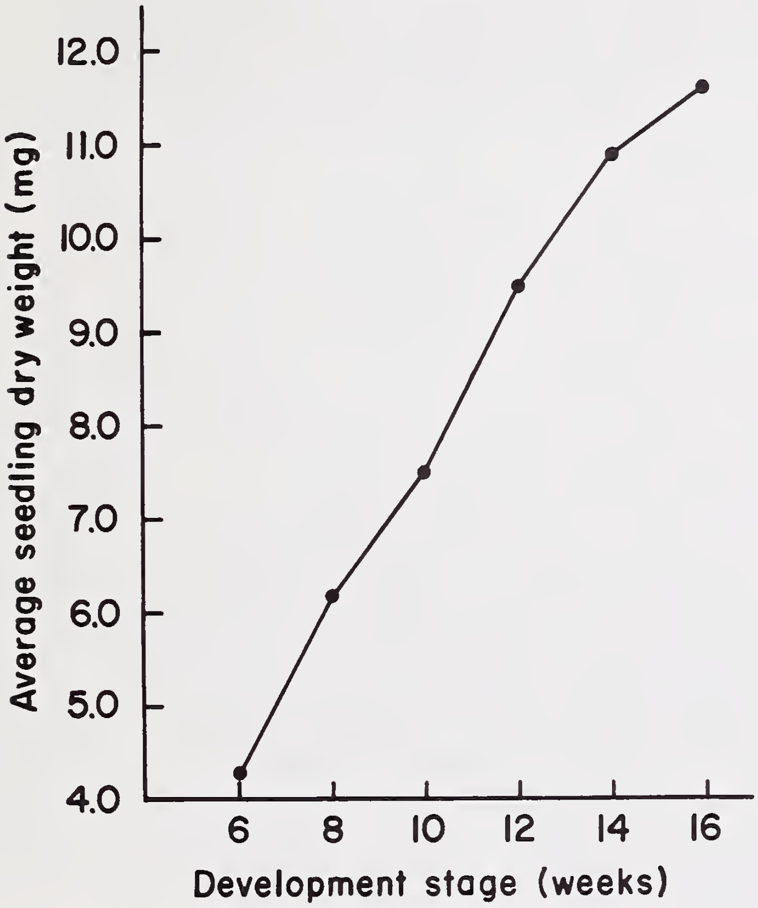

Figure 2.—Average seedling dry weight for each development stage (measured after 30-day recovery period).

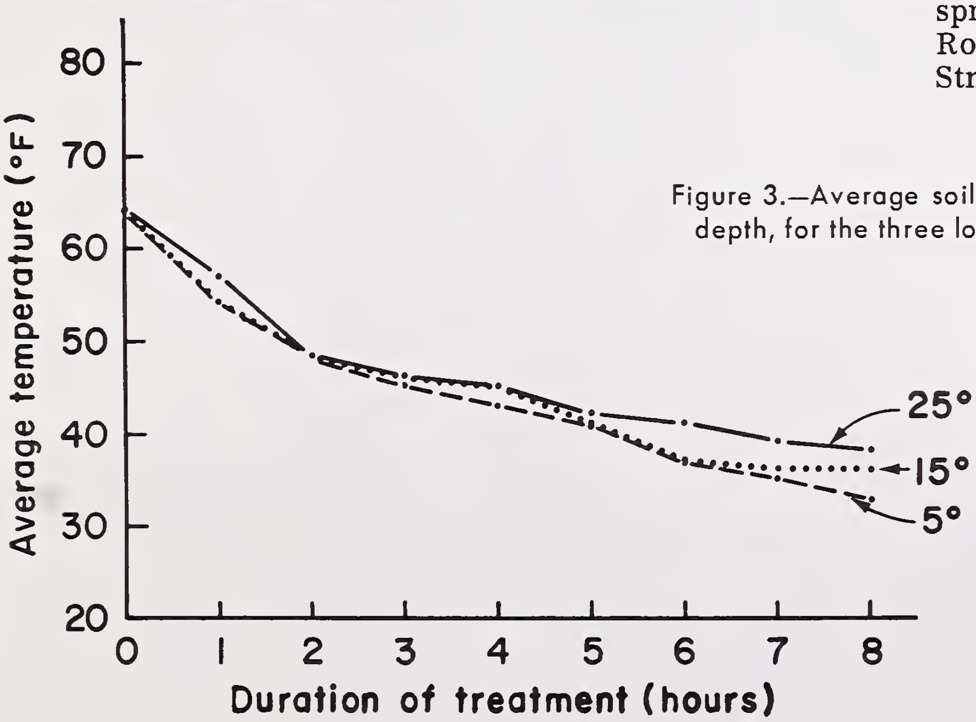

Figure 3.—Average soil temperatures, at 1 to 3 inches depth, for the three low temperatures.

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